DEPARTMENT OF AGRICULTURE,
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IMPROVING WHEATS

BY

SELECTION,

BY

N. A. COBB.

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Experimental Plots.

Any variety can be improved by careful and methodical selection. This method has been in vogue for many ages, and it is to it that we largely owe the gradual improvement that has taken place not only in wheat but in all cultivated plants. There is still plenty of room for improvement, however, and in the present chapter, we point out in particular not only the possibilities ahead, but give plain directions that will enable anyone so inclined to follow up our suggestions. All artificially obtained varieties tend to deteriorate as soon as the care which produced them is withheld, so that even if it were no longer possible to improve the wheat-plant by selection, it would still behove us to practise careful selection for the purpose of keeping up the quality we have already secured.

While it is true that selection can be carried on in the field as ordinarily cultivated, and that this is the method anciently practised and one that is still in vogue, we strongly recommend the putting aside of specially selected and specially tilled land for the growth of plants from which to select.

An experimental wheat-plot must be carefully sown and carefully tended. The question is often asked "is it possible to tell from the way wheats behave in a plot tended with the utmost care, how they will behave when sown broadcast in the usual way? Does it follow that because a wheat turns out well when drilled in and kept free from weeds by continuous cultivating—does it follow that it will do well in the hands of the ordinary wheat-grower?" The reply to these questions is this: "No; it does not follow that a wheat that does well in the one case will necessarily do well in the other; nevertheless experience has shown that in most cases we can tell from the behaviour of wheat in an experimental plot how it will behave in general culture." It would be absurd to say that because a given variety yields in a small experimental plot of one-fortieth of an acre at the rate of 30 bushels to the acre, that it will yield 30 bushels in the hands of wheat-growers generally. On the other hand, however, if on two experimental plots of equal size and similarly treated it was found that one variety yielded twice as much as another, it would be quite safe to say at once that the wheat which yielded the double amount would yield the better in general culture. Experimental plots will never be managed on a great scale on account of the expense. Experiments are ventures, and in most cases failures. There are nine failures to one success and each failure costs just as much as the one success, if not more. It is only when we can apply on a large scale the knowledge gained from successful experiments that the benefits of experimental work are seen. In the case of wheat-growing, experimental plots are so valuable that we advocate their use by all those who grow wheat on a large scale.

To be useful the plots must be situated on land suitable to wheat-culture—such land as is used by the wheat-growers it is intended to benefit. This land should be as uniform in quality as possible, so that we may know when we get certain results that we have not to allow for that unknown element, the fertility of the land. We may illustrate this matter best by a simple example. Suppose we are trying two wheats for their relative productiveness and find that one, the first, yields 10 per cent. more than the second. In such a case our result is worthless unless we know that the land in both cases was the same in every respect. To get uniform land is not easy, but it is not impossible. Small areas sufficiently uniform can be found in most localities. When a uniform area of sufficient size cannot be secured it will often be found that one varying in a slight degree can be secured. Such land may be used for experimental purposes if the change in the land takes place gradually in one direction. Thus if on the slope of a hill or near the bottom, land is found that in the upper part is a little coarser than lower down, we may compensate for this fact to some extent by placing the drills in our experimental plots so that they run in the direction of the change, that is up the hill, so that part of each drill is on the coarser soil and part on the finer. In any case too much attention cannot be paid to this matter of uniformity of soil. A deficiency in this respect has spoiled the results of more experiments in agriculture than any other one cause. In this connection it is well to recollect that the larger the experimental plot the less likelihood there is of the land being of uniform quality; it is all the more necessary to mention this fact because there is a notion prevalent that large experimental plots are to be preferred for the reason that any small irregularity in the land will be made up for in the average result of a large plot. This is to some extent a fallacy. The smaller the plot the more thoroughly we can control its uniformity. The only reason why the smallest possible plot is not the best is that individual wheat-plants vary so much from each other that it is necessary to grow a considerable number in order to obtain reliable results. The number of plants it is desirable to grow varies according to the object of the experiment, but there are few experiments that require the growth of above one thousand plants of a given variety.

In giving directions for the method of cultivating an experimental plot we assume that it is not the object of the experiment to find out the best method of culture; in such a case the experiment itself must determine what kind of treatment the land shall receive. For all other purposes the following will be found a good method :—1. Plough 3 to 8 inches deep. 2. Harrow twice over, across the furrows. 3. If the soil is lumpy break the lumps apart with a spade or mallet after each harrowing. 4. Make perfectly straight parallel drills 16 to 18 inches apart and 2 to 3 inches deep in a direction across the furrows. 5. Sow the wheat by hand, grain by grain, putting only one seed in a place. Sow in an exact line at the bottom of the drill, and place the seed exactly 5, 6, or 7 inches apart as may be desired. If necessary have a line marked every 5, 6, or 7 inches so as to get the seed sown exactly as directed. 6. Cover the seed uniformly 1½ to 2 inches deep. 7. Hoe once every week or ten days, and keep every weed down. 8. In moving about the plot be careful to avoid treading down the earth to the detriment of some plants more than others. A systematic arrangement of paths at right angles to the direction of the drills will be found serviceable in this connection. [See diagram.]

Let us consider each of these eight points more in detail.

1. The best experiments, and the most reliable opinion based on general observation, both favour a firm seed-bed for wheat. Very deep ploughing

immediately before sowing is, therefore, undesirable. Eight inches is not too deep where there is a good rainfall. Where the climate is very dry even 3 inches will answer.

2. Harrowing twice, or three times if necessary, brings the top of the soil into a fine and uniform condition, and harrowing across the furrow accomplishes this object quicker than harrowing with the furrow. Both ploughing and harrowing should be done in a regular and thorough manner, so as to secure regularity in the mechanical condition of the soil. If one part of the plot is ploughed or harrowed differently from any other part, the plants will be growing under different conditions in the two parts, and such plants cannot, therefore, be compared with each other in other respects. If, for instance, the yield is different in the two parts, it will be impossible to say how much of the difference is due to difference in the manner of ploughing and harrowing.

The soil should not be allowed to remain lumpy, for the obvious reason that such soil is less likely to be uniform in quality.

4. The drills should be straight, because the subsequent labour of cultivating and keeping down the weeds is much less if the rows are not crooked, aside from which, if the rows are not straight and parallel, and evenly spaced, some rows will have a better chance than others, and the object is to give all rows the same chance. Experience has shown that 16 inches is

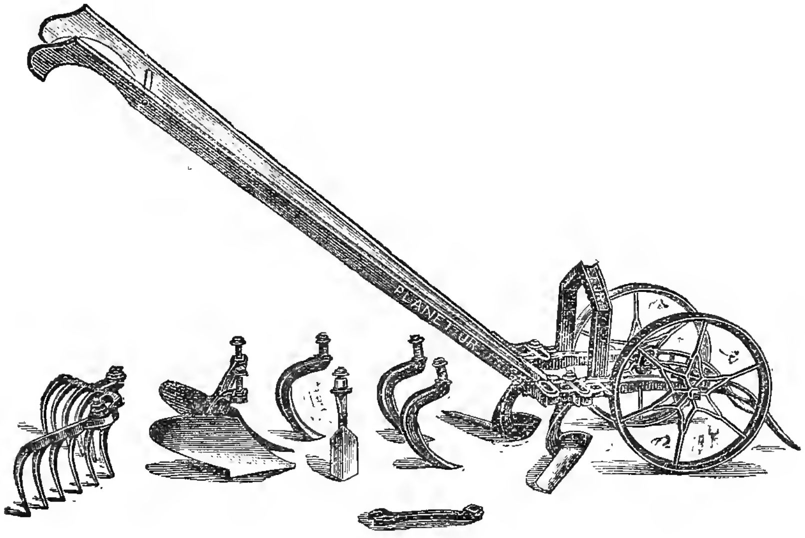


Fig. 1.—Junior Planet Hoe.

a convenient distance between the drills. A drill 2 to 3 inches deep allows of covering at least 2 inches. In general, it is best to cover wheat $1\frac{1}{2}$ to 2 inches deep. Drilling across the furrows gives more uniform results than drilling with the furrows. The harrow fails to obliterate the furrows. If, therefore, the drills are made in the same direction as the furrows, it may happen that one drill lies on the top of what was a furrow,

while the next may lie between two furrows, and the two resulting rows of plants would be likely to differ on that account. We must always keep in mind that we wish to give all rows the same chance. There is no better machine with which to make drills, cover them when sown, and with which to keep down the weeds later on, than the Planet Junior Double-wheel Hoe. There are many planet machines made, with more and different attachments, but the above is the best for experimental wheat-plots. We give the exact name, "Planet Junior Double-wheel Hoe," and a figure of the machine, on page 3.

5. We have never seen a drilling-machine that would drop seed accurately enough for experimental wheat-plots. Moreover, even if such a machine existed, or could be invented, it would be of little or no service. Each lot of seed is so small that the labour of emptying and refilling the machine would more than counterbalance any advantage in quickness of sowing. The only reliable way is to sow by hand, and not to entrust the sowing to any but very reliable persons. More than one seed in a place may lead to mistakes of two sorts. Two seeds close together give rise to stools interlacing, but having the appearance of one stool. Again, each stool is crowded by the other, and consequently grows otherwise than it would if not so crowded. If the seeds are placed exactly by measure each plant will be more likely to have the same chance as every other than if the seeds are not placed exactly. A field line is easily marked every 5, 6, 7, or 8 inches by sowing in a piece of red yarn or tape.

6. The seed is to be covered uniformly for the same reason that all the other operations are performed uniformly. It will be found that good harrowing and breaking up of clods makes the covering much easier.

7. If weeds would only grow uniformly, a few would not do much harm in a wheat-plot, but inasmuch as they will not do so, but will persist in growing nearer some wheat-plants than others, and therefore robbing some more than others, the only safe plan is to extirpate every weed.

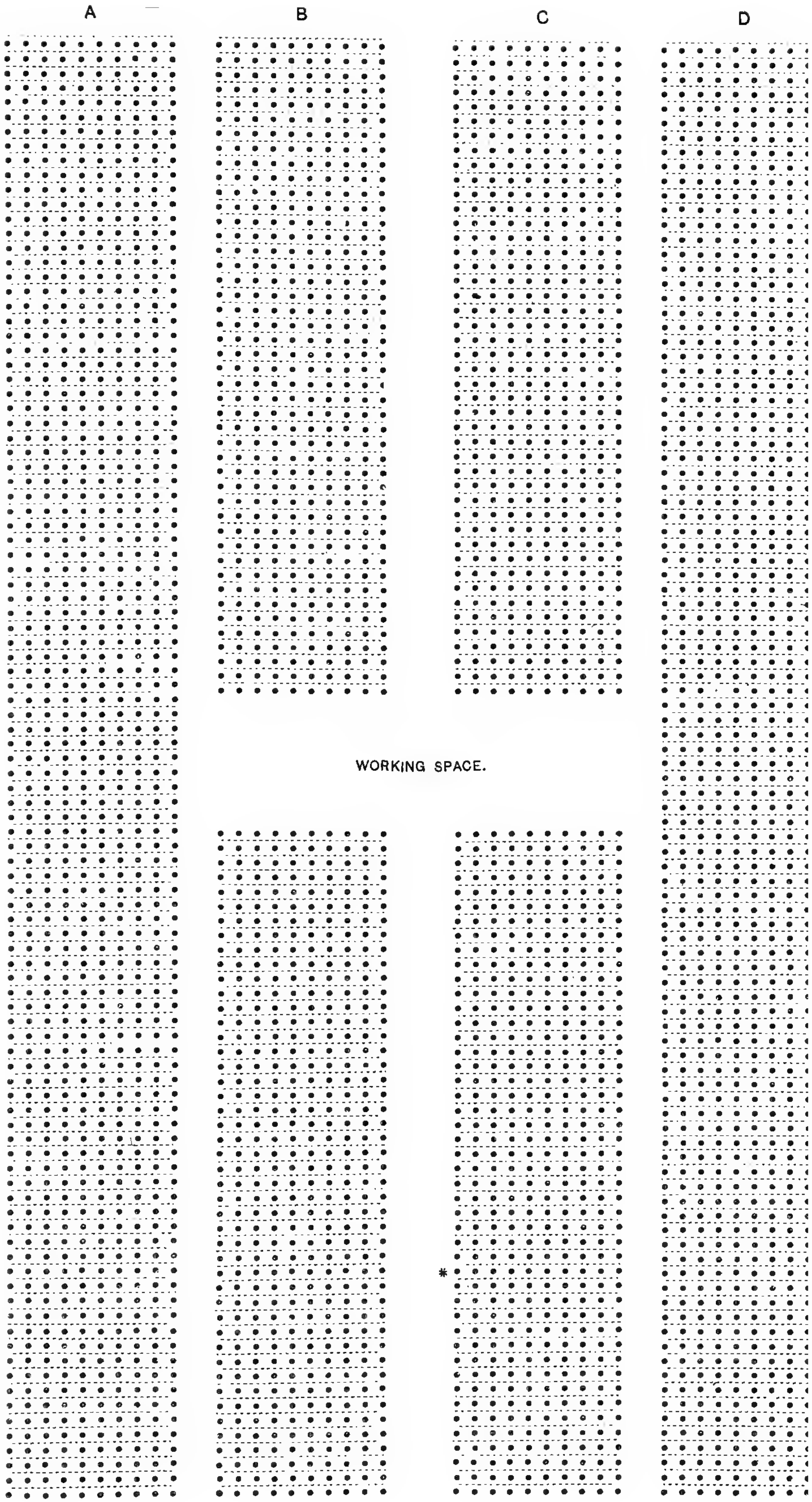
8. We insert here a plan of part of an experimental wheat-plot at Wagga Wagga.

EXPLANATION OF DIAGRAM.

A B C and D are four tiers of wheat, separated by paths, and sown in drills 30 feet long. There are 100 drills in each tier.

Tier A	contains	drills	1 to 100.
Tier B	,,	,,	101 to 200.
Tier C	,,	,,	201 to 300.
Tier D	,,	,,	301 to 400.

This enables us to easily locate any drill. Thus, if we find on referring to our notes that White Lammas is sown in drill 284, we proceed at once to the drill marked with a star. We are enabled to do this the more easily by having every tenth drill of one of the outside tiers indicated by a sign-post bearing its number in characters large enough to be read across the plot. The alternate drills (indicated in the diagram by the faint dotted lines) are sown with a rust-liable variety, as it is our constant object to test our varieties with reference to their resistance to rust. These drills of rust-liable wheat are not numbered; they are regarded as blank. We reserve a space in the middle of the plot as a space to work in at harvest time and other times. This reservation introduces no confusion in the numbering, as we simply fail to sow drills 246 to 254 and drills 346 to 354. By reserving the *centre* of the plot for working room we save much travelling in the course of a season's work. The plot is enclosed with wire netting 3 feet high, to exclude poultry and other animals. This is a wise precaution, as a rabbit or other small animal will quickly make away with a drill of wheat, and is generally perverse enough to select that which is most highly prized.



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We have shown how an experimental wheat-plot should be prepared, planted, and cared for. Let us now imagine the crop to stand before us, and proceed to consider how wheat may be improved by selection, for be it remembered that it is always by selection that wheat is ultimately improved, and that upon the degree of skill shown in selecting, depends the amount of improvement we make. Cross never so skilfully, and then select badly, and the result will be unsatisfactory. To make a cross requires some degree of skill with the hands, and good judgment as to the kind of cross it is desirable to make.* Selection requires qualities of a far higher order.

Wheat is grown in such a variety of ways, harvested and prepared for the market with such a variety of implements, put to such a variety of uses, ground in such a variety of mills, that selection becomes the result of a very complicated set of factors.

In this work we would very willingly avoid the consideration of these numerous factors, but we cannot. The problem before us, namely, that of reducing as much as possible the loss due to rust is too closely connected with them to permit us to ignore them. In fact the reader will see as he goes on that it is these very factors that have more to do with our problem than any others.

The experimental wheat-plot stands before us, presenting a large number of varieties of wheat. Each variety is composed of plants nearly alike, but still no two are exactly alike. Among all the plants in the plot there is one that is best. How shall we find it? If we can but find it, and sow its seed, we shall introduce on our farm a sort of wheat that will yield us larger crops, give us better incomes, and help to reduce the price of the world's daily bread. Surely this is a grand problem to set ourselves to solve, one worthy of our best efforts!

In order to find and select the sort of wheat-plant, which, on the whole, is the best for us to grow, we must consider every factor in the growing, and in the manufacture into food-stuff. We must consider which plants suffer least from rust and of such which yield the largest quantity of good grain. We have already given a scale by which the amount of rust on a given plant may be noted down for comparison with that found on other plants. This scale we believe to be by far the best yet contrived, and the only one with a definite basis, namely the area on the surface of the plant which the rust has succeeded in covering. Our 5 per cent. means that the rust has covered 5 per cent., or one-twentieth of the area of the plant or part examined. Our 10 per cent. means that the rust has covered 10 per cent. or one-tenth of the surface, and so on. Our scale is accurate, scientific. It is at the same time simple and easy of application. The method of application has been already described. It may be well to add that it is equally applicable to sheaths and straw. This is not so readily understood, but is clear at once when we state that the width of the unrolled sheath or straw is the same as, or corresponds with, that of the flag or blade.

The plants to be first selected are those most free from rust. If the experimental plot has been made as directed in the chapter on experimental wheat-plots, that is to say, with every other drill a very rust-liable sort such as Golden Drop, we may be reasonably sure that the plants most free from rust are those having rust-resistant, or rust-escaping properties. But it must never be forgotten that we cannot be absolutely certain of this. It may be

*Note.—The fact that few of the laws that govern the result of a wheat-cross have been discovered, render good results largely a matter of chance. The best compensation for this disadvantage, is the making of a large number of crosses. Out of a large number some good results are sure to follow.

that for some reason we do not know, a particular plant may escape being rusted, and yet possess no great power to resist rust. There is no more practical plan for guarding against this uncertainty than that we have advocated of sowing every other drill with a rust-liable sort.

At this point attention should be directed to the fact that some plants have a power to endure rust. It will be remembered that we proposed the terms rust-proof, rust-resistant, and rust-escaping, as descriptive of different kinds of wheat. To these three might be added a fourth, *rust-enduring*. A rust-enduring wheat is one which, though liable to rust, is able, notwithstanding the attack of the rust, to mature a fair crop of grain under ordinary circumstances. This term has a more limited and less certain application than the other three, but will nevertheless be found useful.

The close-reasoning reader may at this point remark that after all, then, the selecting of least rusted plants is superfluous, since some that are rusted may, in spite of rust, yield better than those not rusted, being rust-endurers, and this remark would be pertinent were it not for the fact that rust-enduring wheats are, to say the least, uncommon, and that furthermore we know at best very little concerning them.

As to the time of the year at which to make observations on rustiness, it may be said that the time when the crop has begun to turn, and after the nature of the yield is no longer uncertain, is the best; but, for reasons to be given later on, the amount of rust at all seasons is worthy of observation.

Having found and marked the least rusted plants, we allow them to mature their grain thoroughly, meanwhile noting how the plants behave in respect to the weather. These considerations are very important, as will be understood at once when we point out that the weather may succeed in so breaking down a wheat as to cause loss in harvesting or cause it to shell so freely as to reduce the yield. When the grain is ripe the relative earliness and yield of the various plants is ascertained, also the nature of their growth as related to harvesting machinery as well as the quality of their grain.

It will be seen from the foregoing brief outline what a large number of things have to be considered before deciding on the best wheat. Let us now make a table of the various points to consider, and then treat each point in detail.

I.—Selecting plants free from rust, or nearly so:—

1. Rust on the flag.
2. Rust on the sheath.
3. Rust on the stalk.
4. Rust on the ear.

II.—Selecting plants for prolificness:—

5. Stooling; number of heads.
6. Sterile spikelets.
7. Number of grains in a spikelet.

III.—Selecting for shape of grain:—

8. Long grain.
9. Pointed grain.
10. Round grain.
11. Shallow crease.
12. Small grain.
13. Small brush.
14. Thick bran or thin bran.

IV.—Selecting plants that hold their grain up to be harvested:-

15. Weak straw.
16. Flexible straw.
17. Stiff straw.
18. Brittle straw.
19. Long and short straw.
20. Beards, at least at the end.
21. Shelling on account of weak chaff.
22. Shelling on account of brittle chaff.
23. Shelling on account of loose heads.
24. Shelling on account of leaning or pendulous heads.
25. Varieties with a red chaff.

V.—Selecting early, midseason, or late wheat:—

26. Earliness and tough cuticle.
27. Earliness and great glaucousness.
28. Earliness and small foliage.
29. Earliness and weak straw.

VI.—30. Selecting plants for shortness of time between earing (not flowering) and ripening.

VII.—31. Selecting plants for narrow erect foliage.

VIII.—32. Selecting plants for toughness of foliage.

IX.—33. Selecting plants for glaucousness.

X.—34. Selecting plants for hairiness.

XI.—Selecting shapely plants:—

35. Heads all at one height.
36. Heads ripening all at the same time.

Our table gives thirty-six points to consider. We shall take these in succession, and devote a short paragraph to each.

I.—Selecting Plants free from Rust or nearly so

Under this head it is to be noted that wheat with a purple straw is almost universally more liable to rust. The so-called purple-straws are mostly very rust-liable. Even among wheats that are more or less resistant to rust, as for instance the Fife wheats, those showing a tendency to purple straws are more liable to rust than those not showing that tendency. The Fifes, as a rule, have whitish or yellowish straw; if, however, a single plant or a strain of Fife shows a slight purple hue in the straw, such plant or strain will usually present more rust than other Fife plants. We have also seen some reason to believe that velvet-chaffed fine wheats (*T. sativum*) are more liable to rust than those with smooth chaff. From this one might argue that if a degree of hairiness could possibly hinder the attacks of rust, it must be a greater degree than we see on any of our present velvet-chaffed sorts.

It will be noticed at once on proceeding to select plants comparatively free from rust that such plants occur more frequently among bearded varieties. Perhaps we might put it better by saying that bearded varieties are relatively freer from rust. There is, however, an objection to bearded wheat on account

of the trouble it gives in threshing. We have made observations and experiments, which we shall present in a later chapter, which lead to the important conclusion that the beard of bearded wheat can be made to drop off in ripening, and therefore cause no difficulty in threshing.

1. *Rust on the Flag.*—It is a common saying that rust on the flag does no harm; but this is false. How any sensible wheat-grower can make such a statement is beyond our comprehension. Did he ever see wheat yielding 40, 50, or 60 bushels to the acre? And did he see any rust on the flag of that wheat? We are sure he would look a long time before finding much. Moreover, one of the very good reasons for the high yield of that wheat was the absence of rust from the flag. Had there been much rust on the flag the yield would never have reached anything like 40 bushels to the acre. One might as well say there is no harm in a horse having only a peck of chaff per day and nothing else. To be sure, he might live, but very little work could be got out of him; he would be about as profitable as rusty wheat at 7 bushels to the acre, and for the same reason, namely, lack of food. What is meant by the declaration that rust on the flag does no harm, is that as long as the rust is confined to the flag there will be *some* grain in the head. This is true; it is equally true that if there is no rust on the flag there will be very much *more* grain in the head, unless some cause that has no connection with rust prevents. We would like to point out, moreover, that every bushel per acre gained by absence of rust from the flag is clear profit, and that it is just such points as these that it is, now-a-days, the most necessary to consider. If there is no rust on the flag there will be none elsewhere. Let us abandon for ever this fallacy that rust on the flag does no harm. Does no harm! Why, the flags are an important part of the breathing system of the wheat plant, and, furthermore, furnish a considerable amount of its food! Would a man be just as well off with one lung, and half-starved? The idea is ridiculous.

If selection for a minimum of rust on the flag takes place among separate plants, then the operation is simply a comparison of the flags of separate plants with each other. In this case no scale of rustiness is absolutely necessary, but it will be found a great convenience. If, however, a large number of plants of one variety are to be compared with a large number of plants of another variety, then a scale of rustiness becomes an absolute necessity if accurate and valuable work is to be done. It is wholly unsafe to take a general look at one variety and then at another, and endeavour to say which is the more rusty, if, as is very often the case, the two differ from each other by no more than 10 per cent. We have frequently done our very best to judge between two sorts under such conditions, afterward testing our judgment by actual measurement. We find that we judge wrongly as often as rightly. The difficulty is all the greater if any amount of time elapses between the two judgments, as in the case of comparing one season's results with another's. How much greater is the difficulty, therefore, in comparing one person's judgment with another's. These remarks on the necessity of a scale of rustiness apply equally to judging the amount of rust on the sheath and straw. The only scale yet proposed, which is based on an absolute unit, is that which proposes to express the amount of rustiness in terms of the area covered by the rust. This method is capable of being carried to any degree of accuracy whatever.

It is hardly necessary to point out that attention has often been confined to the rust on the flag, especially among wheats that have been already worked a season or two, for the reason that the rust occurs nowhere else on the plant.

2. *Rust on the sheath.*—Judging the amount of rust on the sheath is similar in every way to judging it on the flag. Unroll the sheath and it has nearly the same width and appearance as the wider part of the flag, of which it is, in fact, a continuation. Rust is usually less abundant on the sheath than on the flag for the following reasons :—

a. The sheath is vertical, therefore, catches fewer spores.

b. It is more glaucous than the flag, especially than the upper side of the flag.

c. The cell-walls of its cuticle are thicker and tougher.

3. *Rust on the stalk.*—This is judged precisely like that on the sheath. One may easily acquire such facility in comparing the sheath and stalk with the paper rust scale as to make it unnecesary to split them open.

It is a matter of importance to note the kind of rust observed. An idea has been gaining ground that it is possible to dispense with a microscopic examination of the spores before deciding which rust is doing the damage, and we are sorry to say that we have been among those blamable in countenancing this idea. There is no absolutely certain way of distinguishing *Puccinia graminis* from *P. rubigo-vera* except by microscopic examination of the spores, and we have now abandoned every other. In its young stages *graminis* "spots" the flag in the same manner as the *rubigo-vera;* and in the later stages the *rubigo-vera* often "streaks" the stalk in precisely the same manner as the *graminis.*

If much rust occurs on the stalk, above the upper leaf, before the grain is filled, the grain will surely be pinched. The appearance of rust on the stalk, therefore, is a fact to be specially noticed.

4. *Rust on the Ear.*—This is a matter requiring little notice as no particular advantage is gained by knowing about it. It is customary with us, after having gone through a lot of wheat and determined what plants to throw out on account of their rustiness, to go again through the plot at once with a sickle, and remove all the discarded plants. This leaves the plot in better condition for the further selection of the best yielding plants, &c.

II.—Selecting Plants for their Prolificness.

The ultimate test of the prolificness of a plant is the weight of its dry grain. The weighing of large numbers of small lots of wheat is, however, such slow work that we often have recourse to other means of judging the prolificness of a plant especially as there are some objections even to the method of weighing. We find that the ordinary spring-balance sold for weighing mail matter up to 1 lb. is most convenient for weighing the produce of a single plant. Remove the pan supplied with the balance and put in its place a condensed-milk tin of the same weight and nothing better could be desired.

5. *Stooling.*—Good-yielding plants stool or tiller well—that is, produce a large number of heads. A single grain of wheat has been known to produce upward of 100 heads, but thirty to fifty is a very good number. Where a stool appears to have an unusually large number of heads, always look out that the stool did not grow from two grains instead of one. We have seen ridiculous mistakes arise from this source. If the stool be pulled up, and its roots be cut away with a knife, it is usually easy to see if all the stalks start from one grain or centre.

6. *Sterile spikelets.*—It is impossible to judge of the prolificness of a plant by merely counting the heads. It is necessary to know what grain the heads contain. One thing that reduces the amount of grain in some apparently large heads of wheat is the number of sterile spikelets—that is, spikelets at the bottom of the ear which contain no grain. The number of sterile spikelets may reach as high as six or seven. To have a large number of sterile spikelets at the base of its ears is, therefore, a bad quality in a wheat. The plant goes to the trouble of producing chaff, and puts no grain in it; this is waste of energy.

7. *Number of grains in a spikelet.*—This is a matter which determines more than any other the yield of a head of grain, but it is not a mere matter of number; the size of the grain must also be considered. The number of grains may reach five or six; commonly it is three or four. The uppermost grains are smaller than the others—sometimes very much smaller. Many wheats which produce but two grains to the spikelet are nevertheless good yielders, the two grains produced being large and heavy. A variety of wheat varies considerably from season to season in the number of grains produced by its spikelets. Grains sown from a head bearing four grains to the spikelet may give rise to heads with three grains per spikelet, and the reverse may also take place and a three-grain wheat produce four-grain progeny. The exact number of grains depends on the nature of the season, and the method of raising the wheat. If wheat be top-dressed with suitable manure at a time when the heads are first peeping forth, and rains follow so as to wash the manure into the ground, the heads will nearly always produce spikelets with a large number of grains in them. Where wheat is grown on a small scale in mixed farming this is a fact worth knowing, as with suitable means a small area of wheat can be top-dressed to suit the weather.

III.—Selecting for Shape of Grain.

This is a very important part of selecting, the guiding principle of which is the mathematical truth that a round or spherical surface is the one which will enclose the maximum of space for a given amount of surface. Thus, a square inch of surface will enclose the most space if disposed in the shape of a sphere. The application of this principle to the grain of wheat is quite simple. We have to remember that the surface part of a wheat-grain is bran, and of little value as food for man, while it is the great bulk of the interior that is ground up into flour and other food-stuffs. The more nearly a wheat-grain resembles a ball, the less bran it will have in proportion to its flour, and, on the other hand, the more it departs from being round like a ball the more bran it will have in proportion to its flour. From these statements it might be inferred that round-grained wheats are to be preferred, but it will soon be seen that the exact opposite is true, and that long-grained wheats are of the greatest value.

8. *Long grains.*—The value of a grain of wheat as a food producer depends on the amount of food it produces, and the nature of that food. Roughly speaking, the food is of two kinds—starch and gluten. The main portion of the interior of the wheat-grain is starch. Immediately under the bran, however, is a layer of gluten. Gluten is a nitrogenous food-stuff, as meat is, and it is consequently worth more than starch. From this it follows, roughly speaking, that the more gluten a grain contains, the more the grain is worth, providing the gluten is of the right sort. Since the gluten

lies next the bran, and therefore near the surface of the grain, it follows that the greater the surface of the grain is in proportion to its bulk or weight the more gluten it contains, and inasmuch as long grains are those that depart most from the round or spherical shape, they are precisely the grains that contain the most gluten, other things being equal. Thus far the matter is comparatively simple, but complications arise in the following manner: While up to a certain point the gluten in a grain is first in importance, there comes a point at which it is necessary to consider the bran. For instance, let us imagine a grain of wheat to become as long and slender as a sewing needle, its gluten layer would be very large, but along with it, and everywhere covering it, would be bran, and the proportion of bran in such a long and slender grain would be so great as to reduce its value very much as compared with a shorter grain. This would not be the case if the bran were a mere mathematical surface having no thickness; but of course such is not the case, the bran having an appreciable thickness. As a corollary to these facts, it follows that the thinner the bran, the longer a grain can be, and rise in value on that account; or, to put it in another way, thin-skinned wheats should be selected for longer grains than thick-skinned ones. It goes without saying that for centuries it has been an object to reduce the thickness of the bran or skin on the grain of wheat.

9. *Pointed grain.*—A little thought will make it clear that a pointed grain demands more surface than a blunt one to contain a given amount of food-stuff, and therefore will contain more gluten in proportion to its starch.

10. *Roundish grain.*—By a train of reasoning opposite to that given above, it can be shown that roundish grains give less bran to a given weight than grains of any other shape. Connected with this small amount of bran of course is less gluten, unless indeed the gluten layer is thicker than usual, which is sometimes the case with rounded grains. It follows that in selecting wheats yielding roundish grains careful attention should be given to the thickness of the gluten layer, and only those selected that have a thick layer.

11. *Deep crease.*—The general contour of a grain of wheat approaches more nearly to an ellipsoid of revolution than to any other simple mathematical figure, and in the sections immediately preceding it may, for purposes of rough comparison, be regarded as in reality an ellipsoid. In reality, however, it is divided nearly in two by a deep crease; it is, in fact, two ellipsoids joined together. The bran goes to the bottom of the crease; as does also the gluten layer. From this it follows that the deeper the crease the more there is both of bran and gluten, but the grain increases in value with the depth of crease, up to any extent yet known to occur.

12. *Small grain.*—The surfaces of similar solids vary as the squares of their diameters, but the contents vary with the cubes of similar dimensions, from which it follows that it is better up to a certain limit to enclose a given amount of food material in two bran-husks than in one. Compare a large grain of White Lammas, for instance, with a small grain of Allora Spring. Let the White Lammas grain weigh as much as 2 grains of Allora Spring. Then the bran on the two grains of Allora Spring will be considerably greater than that on the one grain of White Lammas, and of course the gluten content of the Allora Spring would be greater if the gluten layer was equally thick in each sort, an assertion which we do not make. It is worthy of notice, though well known, that small-grained wheats give the greatest weight to the bushel.

13. *Small brush.*—The brush is worthless as food. The less there is of it the better.

14. *Thick bran and thin bran.*—For centuries millers have selected wheat for thinness of bran. The thinner the bran the more flour the miller gets from a given weight of wheat, and hence the more profit he secures. This fact has served to call continual attention to the desirability of thin bran. Wheat has accordingly gradually changed, until now ordinary marketable wheat presents a bran thinner in proportion to the size of its grain than can be found on any seed of similar plants (grasses) growing wild. The millers' test for the amount of bran is the best of all, namely, the amount of bran yielded when the wheat is well milled. This test, however, is not applicable by the miller to a small quantity of wheat, a fair-sized mill requiring, when running as usual, about 20 to 50 bushels of grain, in order to give a reliable return as to bran and other products. The only tests that can be applied to small quantities with satisfactory results we believe to be a microscopic examination of a cross-section of the grain. We made examinations some years ago that led us to this belief, and further observations have confirmed our first opinion. In a later chapter we give additional information on this point.

IV.—Selecting Plants that hold their Grain up to be Harvested.

15. *Weak straw.*—By weak straw we mean straw of such a nature that the weight of its own head and foliage causes it to sink down, or lean over and fall down without breaking. To select against weak straw, allow the plants to stand until dead ripe, or even longer, and then harvest only from those plants that still remain upright.

16. *Flexible straw.*—Flexible straw, or that which bends under the weight of the heads and sometimes even allows the heads to hang down, is harder on reaping and threshing machinery than most other sorts, for several reasons. Though flexible straw is usually small, it is always semi-solid, or solid, at least near the top, and therefore it is not more easily cut, on account of its small size, especially by stripping machines. Flexible straw is more likely to become tangled than stiff straw, and is therefore managed with greater difficulty, because it often presents itself to the machine in an oblique fashion. Binding is also a little more awkward where the straws are curved, as is usually the case when they are flexible.

17. *Stiff straw.*—The bad qualities mentioned under flexible straw are a sufficient explanation of why stiff straw is desirable.

18. *Brittle straw.*—Brittle straw is easily broken by the wind, and the heads that fall down from this cause cannot be harvested by machinery. Brittleness is usually caused by the straw being thin-walled.

19. *Long and short straw.*—Whether long or short straw is desirable depends on the market value of the straw and the facilities the farmer has for putting it up ready for the market. As a rule, in the Australian Colonies the straw is not a valuable product, and beyond doubt short-strawed varieties are to be preferred. There are several reasons for this. In the first place, long-strawed varieties shell more because their straw is usually flexible, and the heads, being high above the ground, are more knocked about by the wind. In the second place, the energy (down to a certain limit) which they use up in making straw would be more profitable to the grower if put into making grain. On the other hand, short-strawed

varieties of wheat generally stand up erect and hold their heads erect (an advantage, as we shall see directly), and do not allow the wind to get so much purchase as to batter the heads about and cause the grain to be shaken out on to the ground. The best straw for a variety of wheat is a short stiff one of large diameter having rather thick walls.

20. *Beards.*—Beards on a head of wheat serve to prevent shelling by lessening the shock of impact against other heads when knocked about by the wind. This advantage is counteracted to some extent by their liability to become entangled with those of other heads. Where the heads are thick together, even a few prominent beards at the top of the ear only are an advantage in a gale of wind.

21. *Weak chaff.*—Weak chaff lets the grain fall out. It is thin and flabby, and when the ripe ear is struck smartly the grains fly in every direction because the chaff is not stiff enough to retain its hold on the grain. Weak chaff is the commonest cause of the great evil, shelling. Stiff chaff is usually white or yellow, and is commonly glazed on the surface; its colour is its own. Weak chaff is so thin and translucent as to allow the colour of the grain to show through; its apparent colour, therefore, is derived partly from that of the grain. Weak chaff, when not tinted with red, is usually very white and flimsy-looking; even when tinted with red its white part, where protected by overlying chaff, is equally flimsy looking.

22. *Brittle chaff.*—This is a cause of shelling very distinct from the preceding. Brittle chaff breaks away from the ear too easily. Its attachment to the axis of the ear is easily broken, and when it falls away the grain goes with it. Wheats with a brittle chaff, when ripe and subjected to a few days of dry windy weather, lose all their grain, the top of the stalk being reduced to a mere zigzag.

23. *Loose or open heads versus close or compact heads.*—An ear of wheat is said to be loose or open when the spikelets composing it are separated from each other by a considerable distance. In close ears the spikelets touch each other. It is evident that the latter sorts are less liable to shell, other things being equal. Each spikelet bears against and supports its neighbour, and this hinders the grain from easily escaping from its envelopes. Even varieties with naturally weak or brittle chaff may be wholly or partly prevented from shelling by this means. Loose heads catch more wind, and therefore are more knocked about in a breeze, and this is a disadvantage. From what we have just said it is evident that unless a variety has very stiff and firmly-attached chaff, selection to improve it must be directed towards giving it a compact head. It is doubtful if any advantage whatever results from a loose head.

24. *Leaning or pendulous heads.*—Heads which lean over or hang down are, of course, more likely to lose their grain than upright heads.

25. *Varieties with red chaff.*—So far as we have observed, varieties with red chaff are quite liable to lose their grain by shelling. There are a few marked exceptions however.

V.—Selecting Early, Mid-season, or Late Wheats.

There is a great advantage in sowing wheats that vary as to their time of ripening. In these colonies preference will always be given to early and mid-season sorts. There is no difficulty in the way of selecting for earliness.

We only wish to warn against judging ripeness by the outside appearance of the ear. Judge always by the grain. The ears of some sorts appear quite ripe when the grain is still in the milk, while other sorts harden their grain almost before the ear has ceased to be green.

As selection will hereafter be largely directed toward earliness, we wish to call attention to three or four natural incompatibilities to which it will be necessary to give close attention.

26. *Earliness and a tough cuticle.*—The quick growth of early wheats naturally prevents the processes from being as thorough as in the slower growth of later sorts. This result of pure reasoning is confirmed by observations. The cuticle of early sorts is not as tough as that of late sorts, and this is the reason why early wheats are so liable to rust.

27. *Earliness and great glaucousness.*—Great glaucousness is found in late wheats, but rarely, if ever, in early ones. The reason is probably the same as that for weak cuticle, namely, that the quick growth of early wheats gives little time for the elaboration of the waxy covering that causes glaucousness.

28. *Earliness and small foliage.*—Early wheats have large foliage in proportion to their size. This, again, is in harmony with their quick growth. It will probably be useless to select early wheats for small foliage. If the plants with little foliage be selected the progeny will be later.

29. *Earliness and weak straw.*—Another and often disastrous result of the quick growth of early sorts is weak straw. No early wheats have very strong straw, and the breeder of early wheats will always be obliged to give special attention to this point. The consideration of 26, 27, and 28, is sufficient to show why early wheats are so liable to rust, and it seems probable that, in view of these facts, we must go in for earliness regardless of liability to rust, and not expect to get a wheat both early and resistant. As for the weak straw, that can doubtless be avoided by selection. There will always be a tendency towards dwarfness in early sorts. An attempt should be made to associate earliness with smallish plants, having large foliage and short internode, and especially a short stalk.

VI.—Selecting Plants for their Manner of Ripening.

30. *Shortness of time between earing and flowering.*—The decisive struggle between the rust and the crop takes place on the stalk, *i.e.*, the portion of the straw above the topmost leaf and below the ear. If much rust succeeds in finding a lodgment in that locality before the grain is matured, the ear is, as it were, strangled, or, perhaps better, starved. The grain in maturing draws its food from the leaves and straw below, and this food is passed up to it through the stalk. If, therefore, rust has already attacked and mutilated the stalk, the grain has great difficulty in securing its food. It becomes pinched. The stalk is first exposed to the action of rust after the ears first peep forth, and it remains exposed until ripe. Now, the shorter this time is the less chance there is of the rust gaining a footing on the stalk. It follows, therefore, that the shorter the period between the earing-out of a wheat and its ripening the better. Wheats vary greatly in this respect, and we are satisfied that there is abundant room for improvement of all our varieties in this respect.

31. *Heads ripening all at the same time.*—Some plants have a dawdling way of ripening their ears. Long after the larger and uppermost ears are ripe the others lag. This is a weak point, and should be selected against.

Never use for seed the grain obtained from plants having this irregular habit of ripening. No matter how fine some of the heads may be, their seed can only give rise to plants having the same bad habits. We have observed this again and again.

VII.—Selecting for Narrow, Erect Foliage.

32. The virtue of erect foliage consists in the facts that spores are less likely to find a lodgment on such foliage, and that such foliage is associated with a tough and glaucous cuticle. The latter fact is the more important of the two. Erect foliage is usually narrow and thick for its width.

VIII.—Selecting for Toughness of Foliage.

33. Selecting for toughness of foliage resolves itself into testing the tensile strength of the flag. This is a matter that has occupied our attention for several seasons, and some of the most promising strains of our known varieties have been a direct result of this sort of selection. The matter has been so fully dealt with in chapter VI, that we need not consider it at greater length here.

IX.—Selecting for Glaucousness.

34. The nature and effect of glaucousness, as related to rust, have been described in chapter VI, and we shall, therefore, only briefly allude to the matter here. Plants which, when they are young, have a dark-green colour—that is to say, a dark blue-green, as opposed to a yellowish-green colour—generally begin to acquire a white and waxy (glaucous) appearance as soon as they begin to shoot up. Such plants, on a dewy morning or after a rain, always have what little water has succeeded in clinging to them collected in large drops. They refuse to wet on account of the aversion which their waxy covering has to water. Water does not readily adhere to them. Such plants are more resistant to rust than they otherwise would be. Late varieties of wheat are more inclined to be glaucous than others. Glaucousness is usually associated with a tough cuticle.

X.—Selecting for Hairiness.

35. Hairiness, to be in any way a protection against rust, must obviously be of a greater degree than any known to occur on any part of the wheat plant.

XI.—Selecting Shapely Plants.

36. A model wheat plant should bear its heads as nearly as possible all at the same height. This uniformity in the height of the heads is an advantage at harvest time, as all harvesting and threshing machinery works to greatest advantage on even feed. Where heads are all of the same height they furthermore ripen all at the same time, and, as we have shown, this is an advantage.

This finishes our enumeration of the points that have to be considered in improving wheat by selection. The way in which each sort of selection is made has been also indicated. We have only to add a few words in reference to a systematic way of applying the different selections.

The time to begin the work of selection is while the plants are still entirely green, but are on the point of turning colour preparatory to ripening. There are special points that can be observed to advantage before this period, but on the whole the greatest good with the least labour can be accomplished at about the time specified, which occurs while the plants are in flower and a week or two afterwards. The plants that are compared with each other should be as nearly as possible of the same age. First of all the plants are selected for rustiness; then they are submitted to each test in turn somewhat in the order in which we have given them. The plants which fail to come up to standard are discarded, or cut out altogether. The plants which remain are used as seed the following season, and again improved until a quality is reached suitable for the market. The novice in this work will be surprised at the small number of plants he has left after applying all these tests, perhaps only a few out of a thousand, or even only one. But as he continues year by year he will be gratified by seeing a gradual change for the better in the quality of his experimental wheats, and as the best are used to re-stock the farm, the great good of having an experimental plot will come home to him with irresistible force.

As we have before remarked, we are advocating nothing new in principle. There are already farmers in all directions who have for years, as their ancestors did before them, practised the art of selection. We wish only to call attention to the fact that this matter of improving seed by selection is worthy of the careful attention of everyone who makes his living by raising wheat, and that the experimental plot, even if small and devoted to only a few or even only one variety, is a valuable addition to any wheat-farm. The prosperity of any wheat-grower will be largely in proportion to his heed to the facts we have enumerated.

If no one has previously proposed so precise and elaborate a scheme of selection it is simply because no one has before given the subject sufficient attention; the conclusions we have arrived at are only those which common sense would inevitably reach with a little patient observation and reasoning. We should, perhaps, have been a little less elaborate were it not for the fact that we hope also to secure the attention of specialists, or would-be specialists.

One thing we have, perhaps, not made sufficiently clear. It is this, that all selection should be made by plants, and not by heads. There is a common practice of going through a crop, and plucking the best-looking heads for seed. This is better than nothing, but it may easily happen that the large and fine head is the only good head on the plant from which it was plucked. Its seed, therefore, would tend to produce similar uneven plants to that from which it came. Obviously, the only way to secure good seed without failure is to give full attention to the *whole plant* from which it came.

Harvesting Experimental Wheats.

The harvesting of experimental wheats differs from ordinary harvesting on two accounts—first, the necessity for greater accuracy; and second, the smallness of the lots harvested. Where the crop exceeds half a bushel, ordinary methods are best; but where only a few ounces or pounds of seed are to be harvested, a number of methods are used which will be of service to those who are following the recommendations in the previous chapter.

The reaping is accomplished with a sickle where many consecutive plants in the same drill are to be cut. Our plan is to go ahead of the workman and indicate by pointing the plants to be cut. The workman cuts and binds into sheaves. Where, however, marked plants here and there in a plot are to be harvested the better way is to employ a pocket-knife. The blade may be small. The stalk is cut just below the ears, and

Fig. 2.—Strap and buckle to be used as a belt for supporting calico bags in harvesting experimental wheat. Two wire hooks are attached to the belt as shown in the figure, and upon these the bag is suspended, as shown in Fig. 107.

Fig. 3.—Showing the method of harvesting heads from selected wheat plants. The calico bag is worn as an apron attached to the belt, shown in Fig. 106.

the crop is placed in a bag hung to a strap round the waist, as shown in the accompanying engraving. A label is placed in the bag, as well as tied on outside. It is unnecessary to add that the label should give any necessary specifications, such as kind, quality, date, &c.

The threshing is accomplished by beating the bags containing the heads of wheat on a stone or plank, or by beating the bag with a stick, such as a piece of broom-stick.

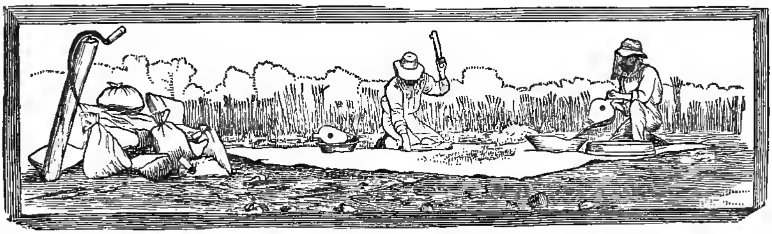

Fig. 4.—Sketch showing method of threshing and winnowing small lots of wheat where the whole yield is only a few pounds or ounces, as described in the text.

The winnowing is done with a winnowing machine, if the grain measures half a bushel or more, but otherwise is accomplished in some other way. It is unnecessary to state that the machine must be scrupulously clean before commencing operations, otherwise the seed might become mixed. If the quantity to be winnowed weighs only a few pounds, it is first sifted in a common round hand-sieve, quarter-inch mesh. This is done on a large piece of canvas, which has been shaken free of seed. The grain is sifted into a large prospector's pan. If the wind is blowing, nothing further is necessary than to pour the seed shoulder-high from one pan to another to winnow it in a few minutes. If there is no wind, a pair of bellows will soon blow the chaff out of the pan, and leave the wheat winnowed. The seed may be

sifted to secure the different sizes—or better, where the quantity is very small (an ounce or two), picked over by hand. The accompanying sketch gives a better idea of the operations than any amount of description. The work is facilitated if a very large movable table can be carried to the plot to lay the canvas on, so as to enable the men to work standing up.

The grain is best stored in bags—not in bottles, or it will soon lose its germinating power. The bags should be of good calico, and should be very

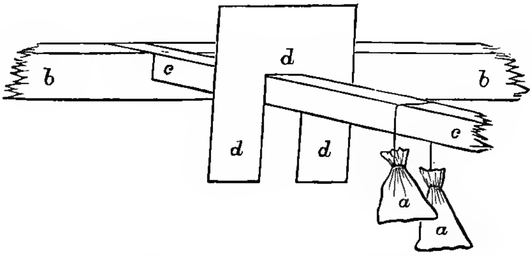

Fig. 5.—Contrivance for preventing mice and rats from getting at wheat hung over a rafter: *a a*, small bags of wheat; *b b*, beam passing along the eaves of barn; *c c*, rafter; *d d d*, piece of sheet iron preventing mice from passing along *c* to the bags. Of course the other end of the rafter has to be guarded by another similar piece of sheet iron.

tightly tied at the mouth. The bags are best hung over a rafter or wire in the loft. We once saw at Mr. Wm. Farrer's farm an ingenious protection against mice, devised by him. It is explained in the adjacent figure.

Sydney: Charles Potter, Government Printer.—1894.

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